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An ISM Approach to Analysis of Enablers of Agile Manufacturing

Deepak Kumar[1], S.P. Agarwal[2], Atul Kumar Mishra[3] and Sumit Kumar Singh[4]

[1]Department of Mechanical Engineering World Institute of Technology and Management, Sohna Haryana, India
[2]Department of Civil Engineering World Institute of Technology and Management, Sohna Haryana, India
[3]Department of Mechanical Engineering World institute of technology and management, Sohna Haryana, India
[4]Department of Mechanical Engineering NGF College of Engineering Technology and Management Palwal, Haryana, India
E-mail: [1]deepakkumar3946@gmail.com

Abstract—*In the highly competitive environment, to be successful and to achieve world-class manufacturing, enterprises need to capable of rapidly respond to changes in customer demand. With Agile Manufacturing we will be able to develop new ways of interacting with our customers and suppliers. A strategic approach to improve the need of customer requirement and implement strategic agile manufacturing (AM) initiatives in the manufacturing organizations. AM is can be adopt and implement due to presence of many enablers. The purpose of this paper is to identify and analyse these enablers. Interpretive structural modelling approach has been used to model and analyse key enablers and analyze the interactions among different agile manufacturing enablers. It identifies the key enablers on which management should focus for the successful implementation of Agile Manufacturing.*

Keywords*: Agile manufacturing, enablers, ISM, Interpretive structural modelling*

1. INTRODUCTION

Today's manufacturing industry is about to experience a drastic change. This change transforms the mass production and lean manufacturing into a new world called Agile Manufacturing. Agile Manufacturing enhances the capabilities of enterprises to come up with the change in the customer demand. It induces new ideas and methods to interact and deal with existing as well as potential customers and suppliers. With this customer will not only be benefitted with the products and services but they will also be able to approach the system and technology so as to meet the exact demands and requirements.

Agile manufacturing can be defined as the potential of sustain and prospering in a competitive environment of continuous and uncertain change by reacting speedily and effectively to changing markets, driven by customer-designed products and services [H. Cho, M. Jung, M. Kim) (1996).

It is not an easy task to implement Agile Manufacturing. Implementation of Agile Manufacturing is always under influence some factors. The factors which influence the success of Agile Manufacturing implementation are known as enablers. These enablers not only influence the implementation of Agile Manufacturing but also have a certain effects on each other, which make it a must to understand their mutual relationship so that driving and driven factors can be identified.

The purpose of this paper is to recognize the mutual interaction of these enablers and identify the enablers which influence the other enablers) and the enablers which are influenced by others. In the present paper, these enablers have been identified through the literature and interpretive structural modelling (ISM) methodology has been utilized in analyzing their mutual relationship. An ISM model has been prepared to identify some key enablers and their managerial involvement in the implementation of AM.

The main objectives of this paper are as:

- To recognize factors which influence the success of Agile Manufacturing implementation in India.
- To find out the relationship between identified enablers using ISM.
- To discuss managerial implication of this research and suggest directions for future research.

2. IDENTIFICATION OF ENABLERS IN AGILE IMPLEMENTATION

In the last two decades several authors have done significant research on identifying enablers of AM implementation. Table 1 presents the summary of different enablers which affects the successful implementation of AM.

Table 1: Enablers of Agile Manufacturing (AM)

S. No.	Enablers	Notation	Description
1	Virtual enterprise formation tool	E1	Facilitates the reconfiguration of the organization

2	Electronic commerce	E2	Fast response, dynamic behaviour,
3	Concurrent engineering	E3	Reduces the elapsed time required to bring a new product to the market
4	Integrated product / production / business information systems	E4	Concurrent development and dynamic revision of integrated process planning / production scheduling solutions
5	Rapid partnership formation tools	E5	Reduce costs and time involved in the process
6	Rapid prototyping tools	E6	Reductions in time and effort to the design and development stages of manufacturing process
7	Physically distributed manufacturing architecture	E7	Capability to adapt to changes without external interventions

3. ISM METHODOLOGY

Interpretive structural modelling (ISM) is defined as a process focused at helping the human being to distinguish what he/she believes, and clearly what he/she does not know. Its most important function is organizational. By the process does not contribute in information or the information added is negligible. The value added is systematically (Farris and Sage 1975). The ISM process changes unclear, poorly expressive mental models of systems into visible and well clarified models. ISM is an interactive learning process. In this technique, various directly and indirectly related elements are structured into a complete organized model (Warfield 1974, Sage 1977). The various steps involved in ISM modelling are as follows.

Step 1: Different elements (or variables), which are related to defined problems, are identified and a contextual relationship is established among elements.

Step 2: A structural self-interaction matrix (SSIM) is developed for elements. This matrix is checked for transitivity.

Step 3: A reachability matrix (RM) is developed from the SSIM.

Step 4: The reachability matrix (RM) is partitioned into different levels.

Step 5: The reachability matrix (RM) is converted into its conical form.

Step 6: A directed graph (digraph) is drawn and transitivity links are removed.

Step 7: ISM model can be obtained by converting diagraph by replacing nodes of the elements with statements.

4. ISM APPROACH FOR MODELING OF ENABLERS

The various steps, which lead to the development of ISM model, are illustrated below.

Step 1: Establishing the contextual relationship between enablers

After identifying and enlisting the 07 enablers through literature review, the next step is to analyze these enablers. For this purpose, a contextual relationship is chosen. This means that one enabler reaches to another chosen enablers. The following four symbols have been used to denote the direction of the relationship between two enablers (*a* and *b*):

- V is used for the relation from enabler *a* to enabler *b*
- A is used for the relation from enabler *b* to enabler *a*
- X is used for both direction relations
- O is used for no relation between two enablers

Step 2: Development of structural self-interaction matrix (SSIM)

Based on the contextual relationship between enablers, the SSIM has been developed. To obtain consensus, the SSIM was discussed with experts. Based on their responses, SSIM has been finalized and it is presented in Table 1.

Table 1: Structural self-interactive matrix (SSIM)

Enablers	E7	E6	E5	E4	E3	E2	E1
E1	O	A	O	A	X	O	
E2	V	A	O	O	O		
E3	V	O	A	O			
E4	O	A	O				
E5	O	V					
E6	O						
E7							

Step 3: Development of the reachability matrix

The next step is to develop the reachability matrix from SSIM. This is obtained in two sub-steps. In the first sub-step, the SSIM format is converted into the initial reachability matrix. In the second sub-step, final reachability matrix is prepared. For this purpose, the concept of transitivity is introduced.

The SSIM is transformed into a reachability matrix format by transforming the information in each entry of the SSIM into 1s and 0s in the reachability matrix. The substitution of 1s and 0s are as per the following rules:

- If the (a,b) entry in the SSIM is V, then the (a,b) entry in the reachability matrix becomes 1 and the (b,a) entry becomes 0.
- If the (a,b) entry in the SSIM is A, then the (a,b) entry in the matrix becomes 0 and the (b,a) entry becomes 1.
- If the (a,b) entry in the SSIM is X, then the (a,b) entry in the matrix becomes 1 and the (b,a) entry also becomes 1.
- If the (a,b) entry in the SSIM is O, then the (a,b) entry in the matrix becomes 0 and the (b,a) entry also becomes 0.

Following the above rules, the initial reachability matrix is prepared as shown in Table 2. After incorporating the transitivity concept as described above, the final reachability matrix is obtained and is presented in Table 3.

Table 2: Initial reachability matrix

Enablers	E1	E2	E3	E4	E5	E6	E7
E1	1	0	1	0	0	0	0
E2	0	1	0	0	0	0	1
E3	1	0	1	0	0	0	1
E4	1	0	0	1	0	0	0
E5	0	0	1	0	1	1	0
E6	1	1	0	1	0	1	0
E7	0	0	0	0	0	0	1

Table 3: Final reachability matrix

Enablers	E1	E2	E3	E4	E5	E6	E7
E1	1	0	1	0	0	0	1*
E2	0	1	0	0	0	0	1
E3	1	0	1	0	0	0	1
E4	1	0	1*	1	0	0	0
E5	1*	1*	1	1*	1	1	1*
E6	1	1	1*	1	0	1	1*
E7	0	0	0	0	0	0	1

Note: *1* entries are included to incorporate transitivity.*

Step 4: Partitioning the reachability matrix

Based on the suggestions of Warfield (1974) and Farris and Sage (1975), the reachability set and antecedent set for each enabler are found from the final reachability matrix. To keep the length of the paper within the prescribed page limit we have presented the result of iteration in Table 4.

Table 4: Results of different Iteration

Enablers	Reachability set	Antecedent set	Intersection set	Level
E7	E7	E1, E2, E3, E4, E5, E6, E7	E7	I
E3	E1, E3	E1, E3, E4, E5, E6,	E1, E3,	II
E2	E2,	E2, E5, E6,	E2,	III
E4	E4,	E4, E5, E6	E4	III
E6	E6,	E5, E6,	E6	IV
E5	E5,	E5,	E5	V

Step 5: Development of conical matrix

In the next step, a conical matrix is developed by clubbing together enablers in the same level, across rows and columns of the final reachability matrix, as shown in table 5. The drive power (DRP) of a enabler is derived by summing up the number of ones in the rows and its dependence power (DEP) by summing up the number of ones in the columns.

Table 5: Conical matrix

Enablers	E7	E1	E3	E2	E4	E6	E5	DRP
E7	1	0	0	0	0	0	0	1
E1	1	1	1	0	0	0	0	3
E3	1	1	1	0	0	0	0	3
E2	1	0	0	1	0	0	0	2
E4	0	1	1	0	1	0	0	3
E6	1	1	1	1	1	0	1	6
E5	1	1	1	1	1	1	1	7
DEP	6	5	5	3	3	1	2	

Step 6: Development of digraph

Based on the conical matrix, an initial digraph including transitivity links is obtained. This is generated by nodes and lines of edges. After removing the indirect links, a final digraph is developed (Fig. 1).

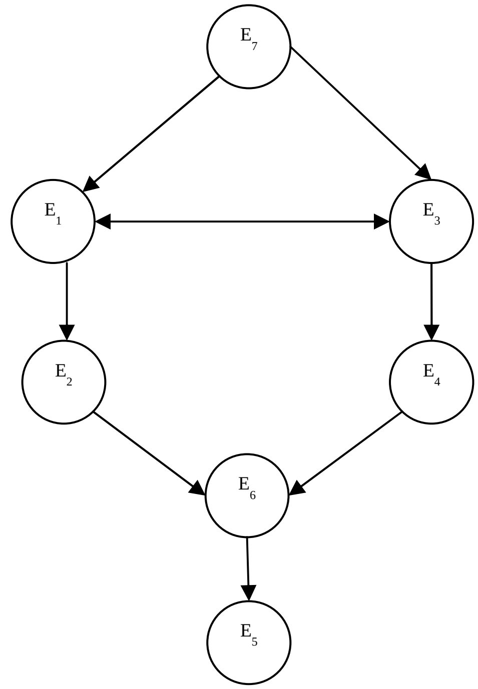

Fig. 1: Digraph showing levels of agile manufacturing enablers

Step 7: Development of ISM model

Next, the digraph is converted into an ISM model by replacing nodes of the elements with statements as shown in figure.

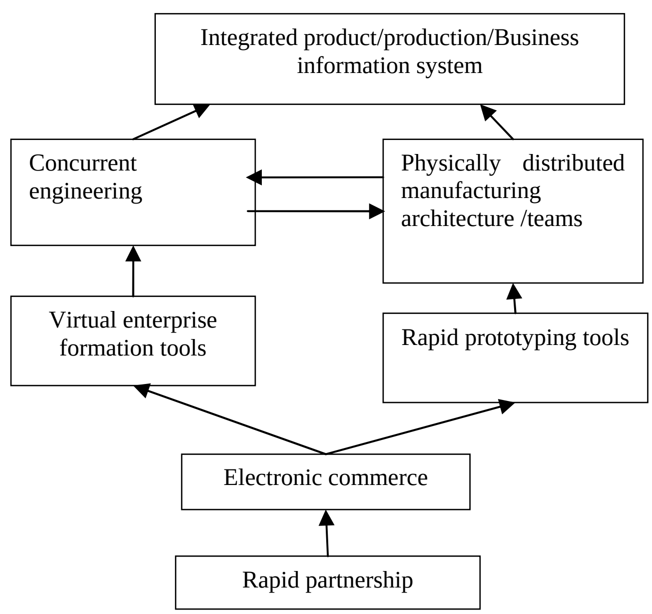

Fig. 2: Interpretive structural model showing levels of Agile Manufacturing Enablers

5. CONCLUSION AND DISCUSSION

The major objective of this article is to identify the enablers that significantly affect the successful implementation of agile manufacturing in any industry so that management may tackle them for successfully implementation of agile manufacturing in their organizations. In this paper, an ISM-based model has been developed to analyze the interactions among different agile manufacturing enablers. It identifies the key enablers on which management should focus for the successful implementation of agile manufacturing. From this study, the following managerial implications have been made:

- The conical matrix (Table 5) shows that there are two autonomous enablers. Autonomous enablers are weak driver and dependent and do not have much influence on the system.
- Dependent enablers are 'concurrent Engineering (E1), 'Architecture and teams' (E_3), and 'Integrated product/business information system' (E7).These enabler are weak drivers and strongly depend on the other enablers. The management should, therefore, accord high priority in tackling the root cause of these enablers. In this process, management should understand the dependence of these enablers on other level enablers in the ISM.
- There is no linkage enabler in the cluster.
- Enablers such as 'Rapid partnership (E6), 'Electronic Commerce (E_5), 'are independent enablers. These enablers have strong driving power and weak dependency on other enablers. They may be treated as the key enablers for the successful implementation of Agile manufacturing. It can also be inferred that these enablers may be treated as the root cause of remaining enablers. To manage these enablers, a comprehensive strategic plan for agile implementation should be formulated to achieve success.

At the end, it would be interesting to examine the scope of future research. In this research, through ISM, a relationship model among the enablers has been developed. This model has been developed on the basis of input from two sources: The major objective of this article is to identify the enablers that significantly affect the successful implementation of agile manufacturing in any industry so that management may tackle them for successfully implementation of agile manufacturing in their organizations. In this paper, an ISM-based model has been developed to analyze the interactions among different agile manufacturing enablers. It identifies the key enablers on which management should focus for the successful implementation of Agile Manufacturing.

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